What To Do With Space

by Clark B. Millikan

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The possible uses of space — some within our present capabilities and some that will open up as we learn more about the space environment.

by Clark B. Millikan

"Space" is a word which for many, perhaps all, of us has acquired a completely new and sometimes disturbing connotation. For many traditionally eastern Americans it has been used vaguely to describe, with appropriate adjectives, the regions to the west which their hardier and more reckless members had in the last century entered, penetrated, and conquered. Hitler attached his own adjective and made it, at least in its German version, a term of opprobrium to our parents and ourselves. I suppose the Russian feeling about space has been related to their endless steppes, as to the mariner it has implied the vastness beyond the horizon of his sea. Astronomers have associated it with the expanses of the universe itself.

Workers and practitioners in aeronautics have been forced into perhaps the most perplexing and difficult adjustment in their concept of the term. For approximately 50 years they had struggled—with, it must be said, considerable success—to understand, master, and utilize a tiny skin around our own planet which constitutes the atmosphere in which we live and through which we have managed to move ourselves and belongings with a rather remarkable degree of regularity, economy, and even swift comfort.

Suddenly, with the first Sputniks, the aeronautical fraternity was projected into an entirely different medium. One thing which made the transition difficult is the fact that there is no sharp barrier between the regions of operation for classical aeronautics and those of outer space. We had been familiar in aeronautics with some rather specific barriers. One, the speed of sound in air, is very precisely defined by the temperature. For example, in the atmospheric temperatures we normally encounter it varies between about 650 and a little over 700 miles per hour. But this anticipated barrier, which had been of great concern as we began to approach these speeds, turned out to be no barrier at all but just a broad region in which a little special engineering care was required, and through which we have, in fact, passed as a quite routine matter.

The region separating "classical aeronautics" and outer space is not similarly definable. It extends over a height of a hundred miles or more, and in this region the fluid properties with which we have been familiar change gradually to those more tenuous than the physicist has ever been able to produce in his most refined small-scale laboratory experiments. Perhaps an even more profound change in the environments than the relatively simple alteration of fluid properties is the fact that outer space is in fact filled with enormously energetic particles and radiations, which are filtered out or degenerated by our atmosphere, so that we are not only protected from them, but cannot even observe them to try and decipher the messages they may be bearing regarding the nature of our universe. Clearly, scientists must be excited about the new exploratory possibilities which have opened up.

For a considerable number of years now, we have been penetrating and even piercing what thus seems more like a blanket than a barrier. The crucial element which has made this possible is, of course, the development of the rocket motor which, for the first time, made it possible for man, within small dimensions, to release enormous amounts of controlled energy in a very short time—producing the tremendous power required to accelerate objects to the velocities (some 25,000 miles per hour) required to get through the resisting blanket of our atmosphere.

A very modest and old-fashioned rocket motor like that of the German wartime V-2 is producing on the order of 10 million horsepower at burn-out, in a machine that is only a couple of feet in length and width, excluding the fuel tanks. This type of device has made possible our whole arsenal of Intercontinental Ballistic Missiles (ICBM's) which constitute so large a share of our deterrent force, designed to keep the world at peace. And these missiles do rise far above our atmospheric blanket in their trajectory from earth launch to earth target. In this sense, then, they belong to the new species of spacecraft. However, I shall exclude them from my considerations here, since their function is essentially unrelated to space as I am using the term.

True spacecraft

Nevertheless, it is the ICBM's, with their urgent military justification, which have in fact led to the possibility of true spacecraft, whose mission and raison d'etre is in the vast volume above our atmosphere. The first Sputnik which circled the globe was almost certainly a device mounted in place of a warhead on top of one of the more or less standard Soviet ICBM's. The Soviets beat us to this achievement, with all its global psychological reactions, for two very simple reasons. The first, political, is well-known: As a US policy it was decided, in connection with the so-called International Geophysical Year, to divorce our satellite effort completely from our military ICBM program. The Russians decided to coordinate *their* efforts to the fullest extent possible, and did so very effectively.

Incidentally, with the failure of our first satellite attempts and the enormous worldwide impact of the Russian success, we made a sudden reversal in our policy. A relatively small ballistic missile already developed by the Army was made available as a first-stage booster, and in the incredibly short time of 88 days Caltech's Jet Propulsion Laboratory put together a series of upper stages which placed *our* first small payload in an orbit about the earth on January 31, 1958. This, by the way, was a much higher orbit than those of the two preceding Russian Sputniks, both of which grazed the atmospheric blanket enough to slow down within a few months, enter the atmosphere, burn up like meteors, and disappear. But our little Explorer I is still whirling serenely in its orbit far above the earth.

The monster

There is a second area, other than that of being first in the race, in which the Soviets are still leading us, and this is in the size of the spacecraft they have been able to launch. The explanation for this lead is also a fascinating and ironic story. In the early 50's our Air Force (and, I am sure, its Soviet counterparts) were studying the possibility of transporting warheads across the vast distances between each other's countries by means of rockets. In fact, contractors to our Air Force had worked out many of the design details of just such an ICBM, carrying the best nuclear warhead then available — a truly monstrous device which taxed the capacity of our largest bomber, the B-29, to get it off the ground. The resulting ICBM was correspondingly monstrous, since the thrust and size of the initial rocket booster stage is directly proportional to the weight and size of the final payload to be delivered.

To even the starryest-eyed of the blue-suit or professional airmen responsible for Air Force policy, such a monster was a little hard to buy, much less sell to Congressional committees holding the necessary purse strings. So they resorted to a device which I am afraid has gotten into our system: They collected a series of committees composed of supposedly unbiased but knowledgeable (and perhaps even, hopefully, wise) civilians to study the problem and advise them. I was unfortunate enough to be chairman of one of the first of these committees. The booster which was described to us, with its cluster of five or seven great rocket engines delivering well over a million pounds of thrust, and its enormously complex pumping, plumbing, and control systems, looked like such a formidable engineering job that we essentially threw up our hands and said, "Back to your laboratories and drafting boards, boys, before you commit yourself to building such a beast."

A year or so later General Benny Schriever, certainly one of the ablest of our military officers—and at the time, I think, a very junior but highly technical colonel—set up a new committee to look at the same problem. This one was headed by the famous mathematician, Johnny von Neumann, and contained unconventional thinkers such as Si Ramo, Pat Hyland, George Kistiakowsky, and several others.

In our deliberations, one factor turned out to be absolutely crucial: Johnny von Neumann had been working with the Los Alamos nuclear scientists who were devoting their lives to the development of improved nuclear devices. The revolutionary concept of the thermonuclear reaction, using fusion of light elements rather than fission or splitting-up of heavy elements, was much in the air there, although protected behind one of the tightest security barriers yet erected. This concept, if it could be made to work, would make the old massive fission bombs completely obsolete, and make it possible to pack enormously more explosive energy into a very much smaller and lighter package.

Although definitive tests were not yet available, Johnny had enough faith in his and his colleagues' calculations to bring to our committee the assurance that these smaller warheads would be available even before the missiles could be produced to carry them. For once, a committee came up with a positive and powerful recommendation, which was: The country should immediately, at the very highest military priority, undertake the design of two alternative boosters, with all the associated and excessively complex gadgetry, to permit the accurate delivery of these anticipated small but potent thermonuclear warheads to distances of at least 5500 nautical miles.

The recommendation was swiftly carried through the military channels to the President himself, who gave his approval. Benny Schriever was given complete authority, normal bureaucratic red tape was essentially eliminated, all necessary funds were made available, and the result, in a phenomenally small number of years, was the family of Atlas and Titan ICBM's which are now being emplaced throughout the vast uninhabited areas of our country, manned by trained military personnel, to constitute our basic deterrent against the Soviet threat of world domination.

Missile gap?

Incidentally, it has become clear that, with the fantastically rapid development of these two weapons systems, the so-called missile gap which was much bruited about a couple of years ago was, in fact, a non-existent fantasy, and that we have in actuality had a considerably larger and more effective ICBM system than have the Soviets at any comparable point in time.

The ironic aspect of this correct and brilliantly executed military decision has become slowly apparent in the non-military or psychological cold war area. It seems now increasingly apparent that, at the time of the monstrous fission bombs, the Russians did not appreciate, or at least gamble on, the future availability of the much smaller thermonuclear warheads. They decided to go all out for the solution of the formidable engineering problems of designing and constructing the million-pound-thrust class of boosters which would be required for ICBM's carrying the then-available fission bomb warheads. This engineering challenge they mastered with amazing competence. Thus, when their own nuclear developments led them to the smaller thermonuclear warheads, they had large, and militarily inefficient, reserves of booster capacity available. From the military point of view it certainly appears that ours was the wiser decision.

But, as the profound implications of the effect on world opinion of putting massive spacecraft into orbit and outer space became apparent, the Russians, with their far larger boosters, had a tremendous advantage. The Soviet spacecraft which have been launched are far more massive and bulky than ours, and although we have now embarked on an impressive large-booster development program, it will clearly be some years before we can launch the size of spacecraft which the Russians already have done. Meanwhile, they will certainly not be standing still.

Successful launches — US vs. USSR

In any case, both we and the Soviets have our emissaries and probers in space and it is indeed fascinating to speculate as to how we shall exploit this newly-discovered capability. First, a word as to the *present* status of matters in this area. As of last fall, the latest date for which I have complete figures, there had been approximately 83 successful launches of US spacecraft and about 28 USSR successes. Many of these have been relatively low-altitude orbit satellites which have fallen back into the atmosphere in a few days or months, so that the then current count of spacecraft orbiting the earth or the sun was 42 for the US and only 8 for the USSR. In the last few months our count has increased considerably while the Russians apparently have been somewhat less active. We have certainly published, and probably have obtained, far more scientific data from our more numerous flights than have the Russians. However, their largest spacecraft, weighing of the order of five or six tons, are far larger than any we have yet sent up, while the great majority of our payloads have been only of the order of a few hundred pounds.

Prior to the first two Russian Sputnik satellites late in 1957 we had in this country only a very meager scientific satellite program, sponsored by the National Academy of Sciences in connection with the International Geophysical Year, during which all of the major powers, including Russia, were joined in a scientific exploration of the earth's lands, seas, and atmosphere. A few, perhaps visionary, officers were considering and even discussing possible military reasons for exploring *space*, but the then Secretary of Defense issued an astonishing directive that the nasty word was not to be used in public addresses, so these visionaries were effectively muzzled.

The impact of Sputnik

The extraordinary worldwide psychological impact of the first Sputnik completely changed our United States attitude towards space. Each of the military services started a frantic program to establish its position in the new environment, and the Congress in 1958, by legislation, set up the National Aeronautics and Space Administration (NASA) to be responsible for the country's non-military or civilian space activities. Both the military and NASA programs soon began an ever-increasing rate of growth which received a still further impetus when President Kennedy, about two years ago, announced the US national program of sending astronauts to the moon and bringing them safely back within the present decade of the 60's.

The government budgets in this area for the fiscal year indicate the fantastic magnitude of our space venture, and suggest the scope of its impact even on our more conventional economic life. The budget figures for '61, '62, and '63 start with 850 million for the military and 900 million for NASA, progress through the fiscal year 1962 with 1 billion, 300 million for the military and 1 billion, 800 million for NASA, and reach the approved figures for '63 of 1 billion, 700 million for the military and 3 billion, 700 million for NASA—a total of $5\frac{1}{2}$ billion dollars. The total 1964 space budget, still under discussion in Congress, is likely to wind up in the neighborhood of 7 billion. NASA's administrator, Mr. James Webb, has estimated that his program will require a total of some 35 to 50 billion dollars over the next decade.

It certainly seems to be no trivial question to ask "What To Do With Space," and unfortunately the answers are highly confused and unclear, so that I shall try only to suggest a few of the things that we can and are certainly going to try very hard to do.

In trying to set up a categorization of the areas in which space may appropriately be exploited, there are some very clear boundaries of demarcation, but there is one very basic factor which may be of overriding importance and which tends to make all the natural division lines hazy and ill-defined. This is the fundamental contest throughout the globe between the Marxist and what we call the Free-Enterprise concepts of the form the world is destined to assume. This is so basic and deep-rooted a conflict that practically every area of human endeavor has its impact upon it. The exciting exploitation of the new space environment is certainly one of the most profoundly influential of human activities in this respect, and such considerations basically affect each of the areas I shall mention. These effects are so profound and complex, however, that it is quite hopeless even to explore them in a brief survey such as this. Accordingly, I propose to ignore them, not because of a lack of awareness of their importance, but because the scope of my remarks would limit me to such an incomplete and fragmentary treatment as to make even the attempt ridiculous.

Manned or unmanned exploration?

There are, then, it seems to me, three basic motivations in the enormously expensive development of the new space environment to which we seem to be irrevocably committed. The first is the exploratory or truly adventurous and scientific motivation which really underlies, or at least is prerequisite to, the other two. It can, as a practical matter, be divided into two separate sub-areas: unmanned and manned. The former is perhaps the more truly scientific in motivation; the second, more in the tradition of the great explorers like Marco Polo, Columbus, Magellan, Livingston, Scott, Mallory, and countless others of our restless heroes.

Our national unmanned scientific space program is a NASA program primarily divided into two parts: the earth satellite, and the lunar-interplanetary regions.

The Earth Satellite Program is essentially the responsibility of NASA's Goddard Laboratory outside of Washington. Most of the 70 NASA spacecraft launches scheduled through 1963 belong in this category. They include orbiting astronomical observatories, orbiting geophysical observatories, and orbiting solar observatories. There are also many experiments to learn the radiation and other characteristics outside of the atmosphere, to test ion and electrical propulsion engines to furnish tiny thrusts for long-time interplanetary travel, and so on.

Many of the planned experiments in this category support other of the space programs mentioned below.

The Unmanned Program

The Lunar and Interplanetary Unmanned Program is assigned to the Jet Propulsion Laboratory (JPL) operated by Caltech under contract with NASA. The first series of spacecraft in this program are called Rangers. They use existing boosters, and are planned to impact, land on, and explore the moon. The highly complicated space operations are controlled from our three great 85-foot radio dishes near Barstow, California; Woomera, Australia; and Johannesburg, South Africa. So far five launches have been made; three failed because of booster troubles, and the other two did not accomplish their intended mission of landing a seismograph on the moon and sending back seismic information by radio. In these two cases malfunctions of components in the spacecraft caused one to impact on the back side of the moon, where all contact with it was lost, while the other missed the moon by some 40,000 miles and is now in silent orbit about the sun. A further series of Rangers is now in preparation, of which it is expected that the first will be launched late in 1963, carrying a television camera to observe the moon's surface as the Ranger approaches for its crash landing. The television pictures will be transmitted to our ground receiving stations by radio.

The next series of JPL spacecraft have been given the name Surveyor. They are being designed to be slowed down by rockets so as to land softly on the moon. They will carry a variety of instruments to make observations of the moon surface and even to drill some distance below the surface, bring up samples of the sub-surface material, subject them to certain physical and chemical tests, and again transmit the results back to earth by radio. These missions will require larger boosters, which are under development by other NASA laboratories, and a total of seven flights is now scheduled for the 1964-65 period.

The initial spacecraft of the JPL Interplanetary Program is the Mariner, which is designed for a series of exploratory flights to the planets Mars and Venus. The first of these flights was launched on August 27, 1962, and, after mid-course corrections carried out upon command from the ground tracking stations on December 14, passed within some 20,000 miles of the Venus surface, which had been the original objective of the flight. As Mariner passed by Venus at a distance of about 36 million miles from the earth, a number of scientific experiments were turned on by command from the Goldstone tracking station.

All of these experiments worked in accordance with their original specifications and a tremendous amount of scientific information was radioed back to earth, where it has been under intensive analysis ever since. From a scientific viewpoint, this represented the greatest achievement which has yet been made in the exploration of space, and has been widely recognized as such. A series of flights of essentially the same spacecraft will be attempted towards the immediate vicinity of Mars during 1964, when Mars and the earth approach one another so as to make such a flight feasible.

As larger boosters become available, a series of more elaborate Mariners are planned to make further scientific studies of Mars and Venus during their "periods of availability" in the 1965-1971 time period. Still later, when the great Saturn boosters enter the picture, a number of larger and more sophisticated spacecraft called Voyagers are planned for unmanned planetary explorations.

Manned Lunar Program

The country's Manned Lunar Program is by far the largest, most expensive, and best publicized of the United States space efforts. The Mercury Program has already carried numbers of single astronauts in orbital flights around the earth, and the Russians have had similar successful orbital, manned operations. The next step in the NASA manned program involves the so-called Gemini, which can carry two astronauts for much longer orbital flights and with which attempts will be made to rendezvous with, and perhaps couple together, two orbiting vehicles. Finally, using the giant Saturn booster, will come the Apollo vehicle, whose objective is to land men on the moon and return them safely to earth within the present decade.

All of these programs fall in the scientific or exploratory area. There are also important military requirements involving space. Here discussion is limited by security considerations, but a few potential military uses of space are quite obvious and have been widely commented on. At this time, these all fall in the category of earth satellites, rather than involving deep space penetrations, and some of the major missions which have been publicly identified are included in the following incomplete list.

A secure global military communication system is essential under the present international conditions, and the use of a system of communications satellites offers great possibilities. Global navigation and the precise location of vessels, aircraft, and targets is of particular concern to the Navy, which has been given primary responsibility for the Transit system, using satellites especially designed to improve greatly our present capabilities in this area. Early warning of an enemy's ballistic missile attack is an essential requirement imposed by our national policy of not ourselves initiating such an attack, and the Air Force Midas system of early warning satellites is an important current program to meet this need.

The basic imbalance between the United States strategic intelligence position vis-a-vis that of the USSR results from the fact that ours is essentially an open country while theirs is a closed one. Our official abandonment of the U-2 reconnaissance program means that reconnaissance by satellites has become a vitally important possibility. Actual bombardment from satellites appears at the moment to be much less effective than attacks by ICBM's, but this may not continue to be the case in the more distant future.

It is clear that there are now, and will develop many more, legitimate military requirements involving the space environment, and that this country cannot afford, any more than in any other area, to permit any potential enemy to develop technological superiority.

Industrial space programs

Turning now to the third of the basic motivations for our involvement in the "space race," namely those in the industrial, commercial, or economic fields, two programs are already being actively pursued. The first is aimed at improving our capabilities in the observation and forecasting of weather. Several Tiros satellites have already been successfully launched and have contributed tremendously. In fact, the Tiros data are now being distributed on a routine basis by the Weather Bureau and are being used most effectively in all kinds of industrial operations. The program will continue with more sophisticated and elaborate satellites which will still further enhance its usefulness. The second program is in the field of commercial global communications. The A.T. and T. Company's Telstar satellite was, as everyone has read, highly successful in intercontinental communications, and other more advanced projects are now under active development.

Why the moon?

There are obviously hundreds of other economic uses of space which we can't even glimpse until we know more about the new environment. Some of the most thought-provoking predictions have been made by Arthur C. Clarke, who has been one of the space visionaries in England for years, and who both writes well and has often had his wild predictions fully confirmed. In an article in *Harper's* ("The Uses of the Moon," December 1961) Mr. Clarke considered the purely economic advantages of a colony of earth people on the moon. A very brief summary of some of his reasoning and predictions will perhaps serve to conclude this brief survey on an appropriate note of somewhat awed speculation. The following pertinent characteristics of the moon underlie his conclusions:

1. Its surface area is 1/16th that of the earth; nearly as much as that of the North and South American continents combined.

2. Its material must be made up of the same basic elements as the earth, such as oxygen, hydrogen, carbon and iron, although in different combinations than we are accustomed to, since our familiar organic compounds will almost certainly be lacking because of the presumed lack of any history of life on the moon. In principle it must be possible to purify or synthesize all of the products needed for life and commerce by some sort of lunar chemistry.

3. Because of its smaller mass the moon's gravitational attraction is only 1/6th of that at the earth's surface.

4. In view of this low gravitational attraction the moon's atmosphere, if it ever had one, has leaked off into space, so that its surface is surrounded by an almost perfect vacuum.

5. The lack of atmosphere means no weather; there is only the extremely large daily variation in temperature (some 500°F) at any point on the moon's surface. But vacuum is an ideal insulation, hence a simple two-surfaced structure with the natural environmental vacuum between will make it very simple to maintain the inside of such a structure at a constant and humanly comfortable temperature.

6. The moon rotates very slowly so that its day and night are a month, instead of 24 hours, long. And the rotation is such that the same side of the moon always faces the earth and the back side is

shielded from all earth disturbances by billions of tons of the lunar mass.

Finally, it seems certain that within the next century controlled thermonuclear power will be developed so that a few pounds of material transported to the moon can furnish enormous sources of energy for activities to be carried out there. Nuclear rockets requiring only hydrogen to be heated and jetted out to furnish rocket thrust are already under contract and are scheduled to be flown in the next five or six years.

What are the potential consequences which may be seen as a result of these special lunar and energy characteristics?

First—Colonies of humans can be transported to the moon, can create a livable and even comfortable environment and produce from lunar materials the requirements for sustaining life and producing hydrogen to refuel nuclear-powered space ships.

Second—Because of the lower gravity, space ships can be accelerated to speeds such that they can return to the earth or explore outer space with only a fraction of the power required for our enormous earth-based boosters.

Third—In view of the absence of atmosphere such vehicles can be accelerated up to moon escape-speed of some 5000 m.p.h., along surface tracks powered by surface-based power plants, and without consuming any precious hydrogen rocket fuel. From earth, with its 25,000 m.p.h. escape-speed and its dense surface atmosphere, this is completely impossible. Our only method for launching space ships from earth is to use enormous booster rockets weighing over 100 tons for each ton of payload sent off.

Thus moon-basing does furnish the first conceivable possibility for any really extensive exploration of space with payloads and costs which make some sort of economic sense. Calculations show that great refueling tankers filled with lunar-produced hydrogen could be sent down to orbit the earth as satellites at altitudes of a couple of hundred miles, ready to service and refuel earth-launched space missions. Here again the economics is tremendously in favor of such a procedure rather than the presently planned one of sending refueling stations up from the earth.

Another industrial area opened up by moon-basing is the large and rapidly increasing number of industries which require high vacuum as part of the production process. On earth, really high vacuum facilities are enormously expensive and large ones are essentially impossible. On the moon, such high vacuums would be just outside the air locks of each inhabited structure, and could be utilized in ways already visualized and others not yet even conceived.

Communication with the outer universe

A final example shows still another great possibility. Communication with, and the receipt of information from, deep space and the outer universe is greatly restricted by our atmospheric blanket and by the terrific radio-type noise emitted by our broadcasting stations, automobile ignition systems, electric shavers, motors, and so on. The far side of the moon is completely shielded from these interferences, and giant radio-telescopes could be built at a fraction of the complexity of their earth-based counterparts, both because of the reduced gravity and the absence of weather disturbances.

These are but a few of the possible uses of space which are already visible and essentially within our present capabilities. The vistas which will open up as we learn more of the new space environment are fascinating and endless. Some of us will hopefully live to see if not to participate in them.

About the author:

Clark B. Millikan is professor of aeronautics and director of Caltech's Graduate Aeronautical Laboratories. His article is a transcript of a talk given to the American Institute of Architects. Dr. Millikan has been on the Caltech faculty since 1928, when he received his PhD from the Institute. He is a member of the Air Force Scientific Advisory Board and of the Scientific Advisory Committee of the Army's Ballistic Research Laboratories. He is a director of the Marquardt Corporation, the Menasco Manufacturing Company, and the National Engineering Science Company. He also serves on the technical advisory board of the Aerojet General Corporation.